Study of Design and Diagnosis System for Locomotive Diesel Based on GPS/GPRS-Internet

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***Abstract*— The fundamental process in the system is obtaining train location using GPS technology and transmitting the data via GSM network to the central control unit for data processing and information analysis. Real-time positioning information received by the server is made meaningful and extremely useful for the end user through integration of GIS technology where the end user can better organize and utilize information from a graphical view point.**

I. INTRODUCTION

It is strongly believe that the correct combination of latest information and communication technologies can provide an effective and feasible solution for the requirement of a reliable and accurate train tracking system to improve the efficiency and productivity of railways. The solution as proposed here encompasses a powerful combination of mobile computing, Global System for Mobile Communication (GSM), Global Positioning System (GPS), Geographical Information System (GIS) technologies and software to provide an intelligent train tracking and management system to improve the existing railway transport service. All these technologies are seamlessly integrated to build a robust, scalable architecture as illustrated in fig. 1.

II. MODULES OF THE SYSTEM

The system consists of 3 main modules.

- The portable hardware unit (GPS/GSM train locator unit)
- Central server which handles receiving information from train locators and concurrent user requests
- Graphical User Interface (GUI) to provide services to the stakeholders

The train locator unit planted in the train is designed and implemented, considering the cost factor, size of the module, durability and low power consumption. The power supply unit of the module is a main factor which decides the feasibility of the unit, as it should sustain a seamless supply of electricity at a low voltage for the locator module to function properly.

The GPS receiver of the unit is capable of identifying the latitudinal and longitudinal position and ground speed of the specific train by receiving information from the GPS satellites. The position data is periodically sent to the central server through the GSM transmitter of the module. The device is capable of storing data in a buffer at a time of GSM connectivity failure, and can synchronize with the remote server when GSM is back online. The device can also respond to commands and data calls from the remote server as per administrative requirements of the train controllers.

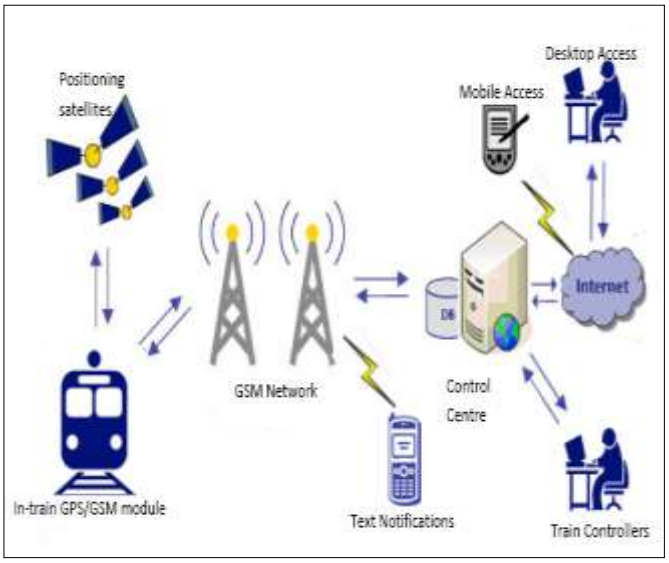


Fig. .1 High Level Architecture

GSM is chosen as the communication medium between the train locator and the central server to improve availability of the system by utilizing the existing GSM network which covers the whole country. The use of GSM over GPRS significantly improves the feasibility and availability of the system. Thus, selection of GSM over GPRS data communication is feasible and enables island wide service provisioning. The competition between the GSM service providers has also lead to high quality GSM services at fair rates. The central control system includes a server for handling and processing all the position information received from train locators via the GSM network. The server automatically updates the database with latest position, speed and direction information of each train. The server carries out information processing and analyzing in order to cater for different requirements of the users of the system. The main stakeholders of the system are the railway administrators (Railway Department), locomotive drivers and the train commuters. The main objective is to be instrumental in improving the efficiency and effectiveness of Railway services by fulfilling the fundamental requirement of reliable and real time information of train positioning for monitoring and administration purposes by the Railway Department. The end user of the system is offered with an easy to use graphical user interface for information analysis and administration tasks. The web based access and

extensible mobile access to the software is designed to be intuitive for the end user to maximize the effectiveness and efficiency of the system.

GIS techniques are incorporated to provide location specific data organized in layers so the end user can better apprehend the information provided by the system. Satellite images providing visual positioning can serve as a very good background when used in conjunction with map data specifying the location. The system essentially provides functionality for the railway administrator to monitor the progress of a particular train or a group of trains operating in a geographical area.

The user can search and locate trains by the train ID, train name, current location or nearest station etc. Information such as train speed, direction can also be given along with real time train positioning data. The train control and management process includes management of heavy traffic of passenger and freight trains, which operates in complex running patterns on the railway network. The train controller needs to ensure that passenger trains are adhering to the schedules as well to find efficient routes for unscheduled freight trains.

Recording the train movements, arrival/departure at railway stations, fuel status, railway track conditions, and passenger information is a tedious task for the train controllers and would be time consuming if done manually. The accuracy of this information is very important to ensure smooth functioning of the railway service as well as to optimize resource planning. For example at a point of a railway-track failure or an accident, train controller should be able to decide on how to utilize existing resources and efficient alternative routes to ensure system availability of the railway service in that region. Thus the train tracking system can be enhanced to automate the train control and management process of the Railway Department in order to improve the efficiency and effectiveness of the railway services provided.

Security Software such as Antivirus, Anti-Intrusion Prevention and Secured Authentication Process shall be provided. System shall provide full Network Monitoring, Performance Logging, Statistics and Management Reporting. The System shall comply with all prevailing Cyber Law and/or Internet Security Law and various stipulations in this regard. All requisite Statutory and Regulatory clearances shall be obtained from Ministry of Information & Broadcasting by Purchaser/System Provider as applicable. System Provider shall demonstrate working of complete system as proposed to be supplied either in a Working Railway System or in Lab Environment before supply to the Purchaser.

III. SPECIFICATIONS:

The equipments architecture, functional, technical, electrical and mechanical requirement etc. for Locomotive Equipment is:

General requirement:

- Locomotive Equipment shall mainly consist of Processing Unit Motherboard, Memory, GPS Receiver, GSM Modem, RF Transceiver, Display, Keypad and Power Supply Module including Inbuilt Battery.
- 'Power On' indication with RED LED shall be available in the Locomotive Equipment, which shall glow when Power is available at the output of Power Supply Module.
- The Locomotive Equipment shall support and work on Open Source Linux Operating System. Latest available version of Linux OS shall be used loaded into Locomotive Equipment.
- Locomotive Equipment shall be capable of working upto 200 Kmph. Locomotive Equipment shall be capable of working in different Railway Electrified Sections (25 KV AC, 1500 V DC & 750 V DC) as well as Non-Electrified sections.
- Equipments, Wires & Cables, Fixing Arrangements etc. to be installed Inside & Outside Locomotives shall be of Fire Retardant Material and shall not cause fire.

Functional requirement:

When powered ON, the locomotive equipment shall display software version on the LCD Display for a period of 5 Seconds. Subsequently locomotive equipment shall acquire GPS co-ordinates and GPS clock. The Internal clock of locomotive equipment shall be synchronized to GPS clock. Current time (24 Hours Format) shall be displayed on top left of LCD display to be displayed till locomotive equipment is powered off. Locomotive equipment shall be capable to display locomotive speed (Kmph) acquired through GPS on top right of LCD display.

Subsequently locomotive equipment shall establish two GPRS connections with MSP (Mobile Service Provider) via two GSM modems. GPRS Connection once established shall be kept CONNECTED until it is broken either because of non-availability of GSM coverage or due to some other reason. The availability of both GPRS connections shall be continuously checked after every 30 seconds.

Technical requirements:

Locomotive Equipment shall have a built-in GPS Receiver for getting GPS co-ordinates (Longitude, Latitude & Altitude), speed and time-stamp from satellite system. The GPS receiver shall comply following specifications.

- Tracking Sensitivity shall be better than -150 dBm.
- Autonomous Positional Accuracy shall be better than 10 Meter.
- Suitable to work with Maximum Altitude of 18,000 Meter
- Suitable to work with Maximum Speed of 200 Kmph.
- Update Rate shall be 1 Hz
- Reacquisition time < 1 Second
- Antenna Short Circuit Protection
- Built-in non volatile RTC with battery backup option.

Climatic requirements:

The locomotive equipment will be required to work inside locomotive where metallic surface temperature under sun goes upto: 75º and inside shade upto: 55ºC max. Minimum temperature can go upto- 10ºC. Humidity during Rainy Weather can go upto 100%. The Locomotive Equipment shall withstand following Environment Testing Requirement.

IV. SYSTEM DESIGN

Overall design:

As shown in Figure 3.2, the Distributed Monitoring and Diagnosis System for locomotive diesel consists of a Diagnosis Centre, a number of Locomotive Depot Data Transfer Stations, Diagnosis Units installed in the locomotives charged by each Locomotive Depot, the GPRS networks and the Internet networks for data communication.

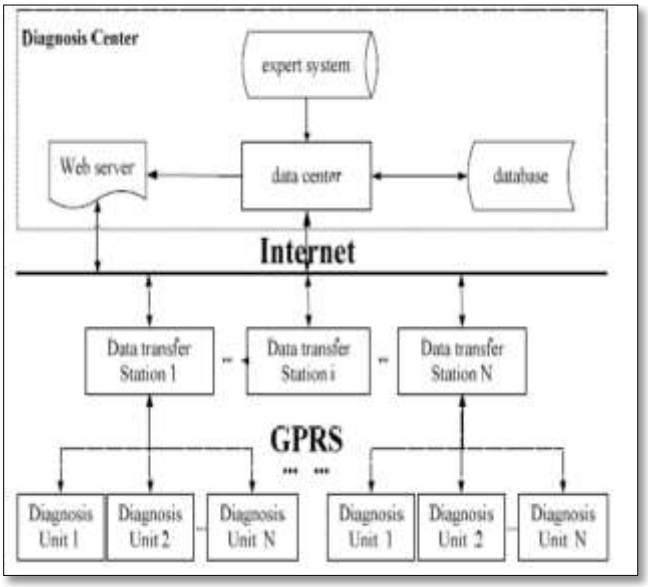


Fig. 2 System Topological Layout

These are described below:

i. Expert System:

Expert systems are computer applications which embody some non-algorithmic expertise for solving certain types of problems. For example, expert systems are used in diagnostic applications. They also play chess, make financial planning decisions, configure computers, monitor real time systems, underwrite insurance policies, and perform many services which previously required human expertise.

ii. Web Server:

Web server can refer to either the hardware (the computer) or the software (the computer application) that helps to deliver Web content that can be accessed through the Internet.

The most common use of web servers is to host websites, but there are other uses such as gaming, data storage or running enterprise applications. The primary function of a web server is to deliver web pages on the request to clients using the Hypertext Transfer Protocol (HTTP). This means delivery of HTML documents and any additional content that may be included by a document, such as images, style sheets and scripts.

A user agent, commonly a web browser or web crawler, initiates communication by making a request for a specific resource using HTTP and the server responds with the content of that resource or an error message if unable to do so. The resource is typically a real file on the server's secondary memory, but this is not necessarily the case and depends on how the web server is implemented.

iii. Data Center:

A data centre (sometimes spelled data centre) is a centralized repository, either physical or virtual, for the storage, management, and dissemination of data and information organized around a particular body of knowledge or pertaining to a particular business. A data centre or computer centre (also data centre) is a facility used to house computer systems and associated components, such as telecommunications and storage systems. It generally includes redundant or backup power supplies, redundant data communications connections, environmental controls (e.g., air conditioning, fire suppression) and security devices.

The National Climatic Data Centre (NCDC), for example, is a public data centre that maintains the world's largest archive of weather information. A private data centre may exist within an organization's facilities or may be maintained as a specialized facility. In that sense, data centre may be synonymous with network operations centre (NOC), a restricted access area containing automated systems that constantly monitor server activity, Web traffic, and network performance.

iv. Database:

A collection of information organized in such a way that a computer program can quickly select desired pieces of data. For example database of an electronic filing system.

v. General packet radio service (GPRS):

General packet radio service (GPRS) is a packet oriented mobile data service on the 2G and 3G cellular communication system's global system for mobile communications (GSM). GPRS was originally standardized by European Telecommunications Standards Institute (ETSI) in response to the earlier CDPD and i-mode packet-switched cellular technologies. It is now maintained by the 3rd Generation Partnership Project (3GPP). GPRS usage is typically charged based on volume of data. This contrasts with circuit switching data, which is typically billed per minute of connection time, regardless of whether or not the user transfers data during that period.

GPRS data is typically supplied either as part of a bundle (e.g., 5 GB per month for a fixed fee) or on a pay-as-you-use basis. Usage above the bundle cap is either charged per megabyte or disallowed. The pay-as-you-use charging is typically per megabyte of traffic.

GPRS is a best-effort service, implying variable throughput and latency that depend on the number

of other users sharing the service concurrently, as opposed to circuit switching, where a certain quality of service (QoS) is guaranteed during the connection. In 2G systems, GPRS provides data rates of 56–114 kbit/second. 2G cellular technology combined with GPRS is sometimes described as 2.5G, that is, a technology between the second (2G) and third (3G) generations of mobile telephony. It provides moderate-speed data transfer, by using unused time division multiple access (TDMA) channels in, for example, the GSM system. GPRS is integrated into GSM Release 97 and newer releases.

The GPRS core network allows 2G, 3G and WCDMA mobile networks to transmit IP packets to external networks such as the Internet. The GPRS system is an integrated part of the GSM network switching subsystem.

vi. Data Transfer Station:

Data Transfer Station, we can find three important parts- data receiving server, FTP server and operating station of Locomotive Depot. The data receiving server communicate with the GPRS module to receive data from Diagnosis Unit. The FTP server realizes the data transmission between Data Transfer Stations and Diagnosis Centre allowing Diagnosis Centre to interact with these received data. Operating station of Locomotive Depot can perform data querying and day to day management by saving data in local hard disk and setting up a small local database system.

vii. Diagnostic Unit:

Diagnostic Unit is composed of the parameter acquisition modules, human-computer interaction module and the GPRS wireless communication module. The parameter acquisition modules include the diesel engine instantaneous speed acquisition module, the turbocharger temperature and pressure acquisition module, the generator voltage and current acquisition module, the fuel throttle rod displacement acquisition module and GPS module.

viii. Description of overall design:

The Distributed Monitoring and Diagnosis System for locomotive diesel consists of a Diagnosis Centre, a number of Locomotive Depot Data Transfer Stations, Diagnosis Units installed in the locomotives charged by each Locomotive Depot, the GPRS networks and the Internet networks for data communication. Diagnosis Unit, which is installed in the running locomotive, collects the real- time parameters of operating conditions including GPS information. It can also diagnose operating condition of locomotive diesel online. Data Transfer Stations are placed in Management Department of each Locomotive Depot and process the GPRS sending and receiving. At the same time, Data Transfer Station is used as a FTP (File transfer protocol) server. Diagnosis Centre is composed of several computers connected to the Internet. It manages information of all locomotive diesels in this system. Data communication between Diagnosis Unit and Diagnosis Centre is established through the GPRS network and the Internet via Data Transfer Station. First of all, the signal acquisition module of the Diagnosis Unit monitors the real-time status parameters of locomotive diesel, GPS module RC87 gets the real-time locating information and GPRS module MC55 sends the data collected to Data Transfer Station of the corresponding Locomotive Depot. Secondly, through Internet, the server at Diagnosis Centre reads data of all locomotive diesels of each Locomotive Depot in an agreed period. Then, it analyzes the data and publishes the diagnosis results to the Web servers. Finally, administrator of each Locomotive Depot can login website of Diagnosis Centre for information and technical advice through Internet.

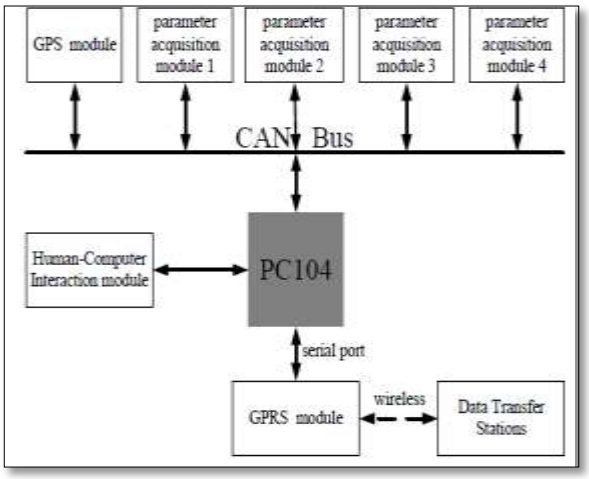


Fig 3. Diagnosis Unit hardware structure

✓ **GPS Module:**

New improved GPS Module with built-in antenna and memory back-up. This unit features low power consumption and high sensitivity. The unit is ideal for navigation systems, distance measurements, vehicle monitoring and recording, boating direction and location, together with linking and cross country exploring. This module includes high precision surface mount technology to provide both high accuracy and very compact size. The module can be easily installed on a main board, with all inputs using standard TTL signal levels. A series of standard messages are provided to give position, satellite information, time, etc. The module can be easily connected directly to a microcontroller to display and record this information.

a. This GPRS module / GPS module as a glance

- Small, lightweight and easy to integrate
- Low power consumption
- Internal SIM card reader and option on external SIM card reader
- Easy GPRS relieves from writing the TCP/IP code and making Internet access as simple as dialling a phone number.
- Always connected with higher data transmission speed
- High performance on low price

✓ **Parameter Acquisition Module:**

The parameter acquisition modules include the diesel engine instantaneous speed acquisition module, the turbocharger temperature and pressure acquisition module, the generator voltage and current acquisition module, the fuel throttle rod displacement acquisition module and GPS module.

✓ **PC/104:**

PC/104 (sometimes also known as **PC104**) is an embedded computer standard controlled by the PC/104 Consortium which defines both a form factor and computer bus. In computing, the form factor is the name used to denote the specifications of a motherboard - like dimensions, power supply type, location of mounting holes, number of ports on the back panel, etc. An embedded system is a computer system designed for specific control functions within a larger system, often with real constraints. PC/104 is intended for specialized embedded computing environments where applications depend on reliable acquisition despite an often extreme environment. The PC/104 computer bus (first released in 1992) utilizes 104 pins. These pins include all the normal lines used in the ISA bus, with additional ground pins added to ensure bus integrity. Signal timing and voltage levels are identical to the ISA bus, with lower current requirements.

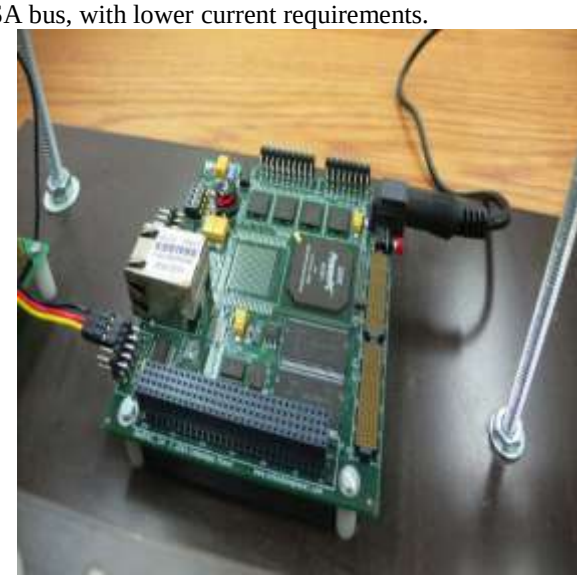


Fig .4.

✓ **Can bus:**

CAN bus (for controller area network) is a vehicle bus standard designed to allow microcontrollers and devices to communicate with each other within a vehicle without a host. CAN bus is a message-based protocol, designed specifically for automotive applications but now also used in other areas such as industrial automation and medical equipment.

✓ **Description of Diagnostic Unit:**

Diagnostic Unit is composed of the parameter acquisition modules, human-computer interaction module and the GPRS wireless communication module. The parameter acquisition modules include the diesel engine instantaneous speed acquisition module, the turbocharger temperature and pressure acquisition module, the generator voltage and current acquisition module, the fuel throttle rod displacement acquisition module and GPS module. These five modules have composed five nodes on the CAN network. PC104 as the MCU, carries on the diagnosis according to the acquainted parameters.

The GPRS module performs a communication platform between Diagnosis Unit and Data Transfer Station according to TCP/IP networking protocol.

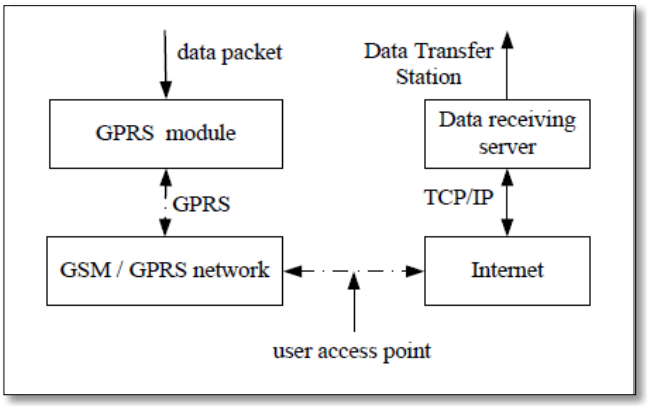


Fig 5.GPRS communication modules

As Shown in figure 5, PC104 encapsulate the diagnosis data into a package according to a custom protocol, and send the package to the GPRS module through the serial port. Then, the GPRS module divides the data package into TCP/IP packet, sends the TCP/IP packet to Data Transfer Station connected to internet. Finally, the GPRS receive server of Data Transfer Station reverts the packet to the original data by means of protocol stack. So, the wireless transparent transmission from the Diagnosis Unit to Data Transfer Station is realized. PC104 as the core of Diagnosis Unit adopts Linux-2.6.0 version as operating system, C++ as an application development language.

✓ **Data Transfer Station:**

In Data Transfer Station, three important parts are- data receiving server, FTP server and operating station of Locomotive Depot.

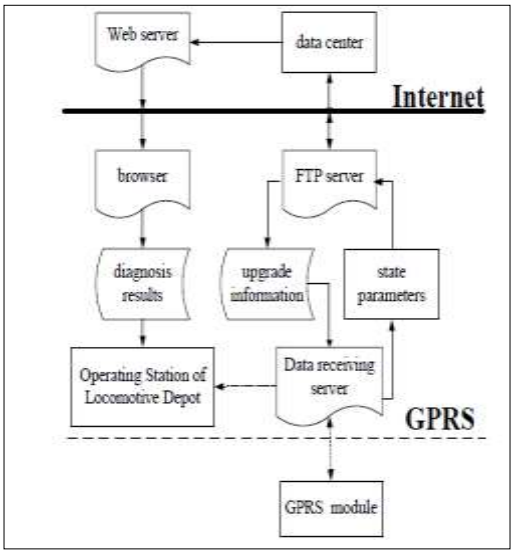


Fig 6. Data Transfer Station block structure

✓ **File transfer Protocol (FTP) Server:**

File Transfer Protocol (FTP) is a standard network protocol used to transfer files from one host to another host over a TCP-based network, such as the Internet. It is often used to upload web pages and other documents from a private development machine to a public web-hosting server. FTP is built on a client-server architecture and uses separate control and data connections between the client and the server. The first FTP client applications were interactive command-line tools, implementing standard commands and syntax. Graphical user interfaces have since been developed for many of the popular desktop operating systems in use today including general web design programs like Microsoft Expression Web, and specialist FTP clients such as Cute FTP.

✓ **Client-Server:**

Client/server describes the relationship between two computer programs in which one program, the client, makes a service request from another program, the server, which fulfils the request.

✓ **Description of Data Transfer Station:**

In Data Transfer Station, we can find three important parts- data receiving server, FTP server and operating station of Locomotive Depot. The data receiving server communicate with the GPRS module to receive data from Diagnosis Unit. The FTP server realizes the data transmission between Data Transfer Stations and Diagnosis Centre allowing Diagnosis Centre to interact with these received data. Operating station of Locomotive Depot can perform data querying and day to day management by saving data in local hard disk and setting up a small local database system. It can also get detailed diagnosis results given by Diagnosis Centre by means of IE browser.

Shown in figure**????**, firstly, the data receiving server receives all the diagnosis data of a Locomotive Depot, and saves in an appointed file folder. Then, through the network based on Internet FTP connection, Diagnosis Centre automatically draw the information from each Data Transfer Station in an agreed period. At the same time, when the diagnosis software and the calibration data need to be upgraded, the update information will be inputted into Data Transfer Station at the Locomotive Depot through the FTP connection, and then be sent to Diagnosis Unit through the GPRS module.

In Data Transfer Station of the Locomotive Depot, a database application software developed with Visual C++ 6.0 and Internet Explorer browser or other types of browser are installed in the operating station, data receiving sever and FTP server are settled in the same embedded computer which is always online.

✓ **Diagnosis Centre:**

Diagnosis Centre can figure out the dynamic changes of locomotive, prevent fault and propose suggestions of maintenance by analyzing the trend of locomotive state parameters. As shown in Figure 3.7, technical personnel of Locomotive Depot have the authority to query the locomotive state data and the diagnosis results for a specified locomotive.

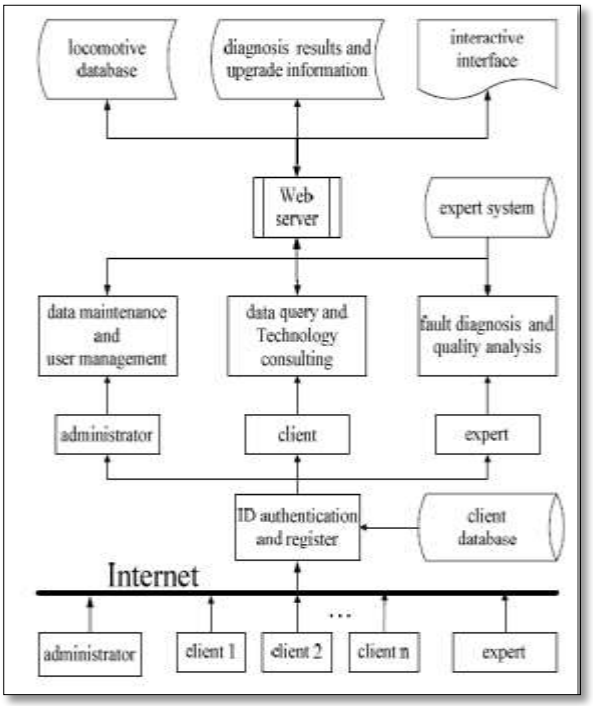


Fig .7 Diagnosis Centre block structure

i. Locomotive Database:

The Locomotive Database is one of the more ambitious initiatives of IRFCA (Indian Railways Fan Club Association). It aims to collect and record information about every single locomotive that is or was running on the IR (Indian Railways).

ii. Interactive Interface:

It forms an interactive platform for communication between the Diagnosis Centre and the locomotive depot. This received information helps in providing interface for the exchange of information so that the stakeholders i.e. the railway administrators, locomotive drivers and the train experts can access the information about the locomotive.

iii. Description of Diagnosis Centre:

Diagnosis Centre can figure out the dynamic changes of locomotive, prevent fault and propose suggestions of maintenance by analyzing the trend of locomotive state parameters. As shown in Figure 3.7, technical personnel of Locomotive Depot have the authority to query the locomotive state data and the diagnosis results for a specified locomotive. They can also ask experts online for technical advice through the network. So the main work of the experts is fault diagnosis based on the state parameters of locomotive by using expert system DB. Administrators should make data backup for the state data and diagnosis results regularly, publish diagnosis results and upgrade information timely, and carry out maintenance and management for the severs in Diagnosis Centre.

Data transmission mode between Locomotive Depot and Diagnosis Centre adopts B/S (Browser/Server). Working as a client, Locomotive Depot only need to install the operating system, network protocol software and browser, so it is called "thin Client". The relationship between the browser and the server is "request/response". Locomotive Depot browser sent a request instruction to the database server. When the server received request it will operate database by SQL and send the operation results back to the Locomotive Depot by form of HTML (Hyper Text Mark-up Language). Data transmission between the browser and server is based on HTTP (Hyper Text Transfer Protocol).

Diagnosis Centre adopt NT based Windows 2003 Server as the network operating system, Microsoft SQL Server 2000 as the backstage database management system, and IIS6.0 provided by Windows 2003 Server as Web server.

V. Fault Diagnosis Characteristics of Electrical System of Electric Locomotive

The fault diagnosis of electrical system of electric locomotive is the most complex. It involves electric locomotive of the main circuit, auxiliary circuit and control circuit. The representative result is electrical fault diagnosis system based on the logic control unit of electric locomotive. The monitoring devices and computer counters of the train have the monitoring and diagnosis functions partly.

Electric locomotive electrical system is a complex time-varying dynamic system, characterized by a specific description is as follows:

- **Levels:** It is the most basic feature of fault because of the layers of system structure, reflecting the fault vertical transmission.
- **Dissemination:** There are two modes of transmission: horizontal transmission, such as the fault of a particular element layer spreading to other elements disorders; vertical transmission means that components fault has caused the fault of their subsystems.
- **Concurrency:** Multiple faults occur simultaneously. This has two reasons: firstly, the different parts of the system fault occurred, the other is a primary fault may be the spread of the existence of many paths, resulting in possible multiple faults at the same time.
- **Delay:** The delay means that the fault of the generation, Development and formation is a process of quantitative change to qualitative change. It has a time delay of fault.
- **Uncertainty:** Uncertainty of complex equipment fault diagnosis is an important characteristic of the diagnosis and is currently an important aspect of theoretical research. Uncertainties include the fault of fuzziness and randomness of the two features.

Electric locomotive electrical system faults have complex forms. Currently, internal and international electric locomotive equipment fault diagnosis method mainly based on information fusion fault diagnosis methods, neural network fault diagnosis methods, expert system locomotive equipment fault diagnosis methods, and artificial intelligence methods and so on.

VI. Fault Diagnosis Theory and Method of Electrical System of Electric Locomotive:

Electric locomotive is a complex dynamic system; locomotive fault diagnosis is based mainly on a series of information produced by the running locomotive to identify equipment faults and trends. Fault diagnosis methods can be divided into the following categories:

- **Methods based on mathematical model:**

Its advantage is that it can study the dynamic nature and real-time diagnosis, can predict the diagnosis of failure, and does not require knowledge of historical experience. However, because of the complexity of the systems, mathematical model of the access is very difficult.

- **Methods based on signal processing:**

It avoided the difficulties of mathematical model of the access, diagnoses through information processing and feature extraction. In particular, it fits in fault information includes acoustic vibrations in the components or unusual spectrum of voltage and current signals.

- **Methods based on artificial intelligence:**

Fault tree method are based on fault analysis in the locomotive electrical system, the electrical system which is divided into several subsystems, characterized by fault-tree structure as fault and achieves fuzzy reasoning by fault fuzzy analysis.

- **Expert systems method:**

Diagnosis Expert System has a concise expression of knowledge, rationality, flexibility and transparency, and easy diagnostic reasoning and so on. However, the knowledge acquisition "bottleneck", the rules of "combinatorial explosion", the reasoning process of low efficiency as well as the strong dependence of the machine system limit its broader, more comprehensive applications.

- **Fuzzy logic method:**

Fuzzy theory can effectively deal with system uncertainties, measurement inaccuracy, can better describe the system and the measurement data and can be fully applied the experience of staff and other information. The key is to determine the fuzzy relation; the method is suitable for specific audiences and complex large-scale systems.

- **Neural network method:**

Artificial neural networks has its own characteristics, such as parallelism, self-learning and associative memory function so that it can resolve the problem which those outstanding traditional pattern recognition methods can hardly solute. However, judging from the many applications, ANN only deal with soft information as a tool to deal with at the local problem on obvious advantages, but the indicators on system behaviour, there are not reported dominantly.

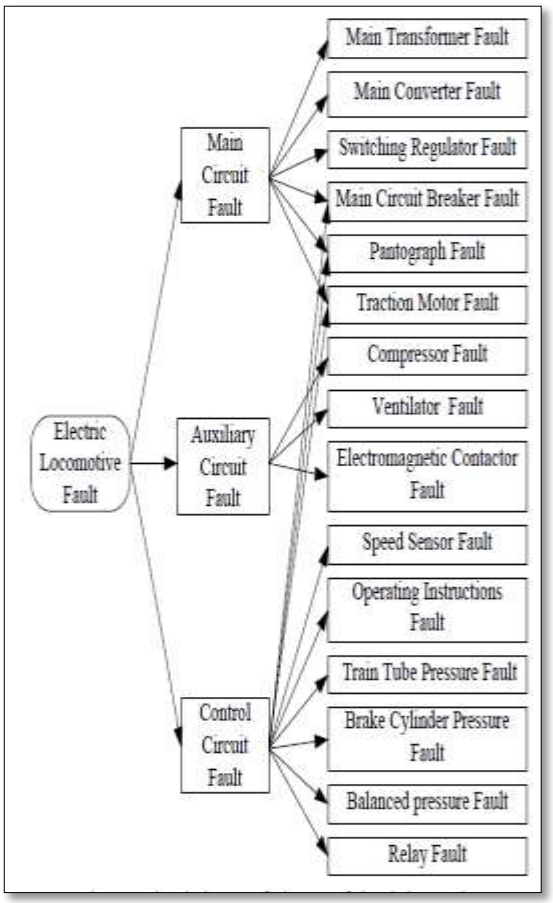


Fig 8. Electrical system faults type of electric locomotive

VII. MAS Theories and Methods of Electrical System of Electric Locomotive:

Agent theory and technology are important research areas of distributed artificial intelligence. Each Agent has certain problem-solving ability, such as reasoning, planning, consultation, communication, and coordination capability. MAS include a number of agents, whose knowledge, data and control distributes in a number of processors on the node.

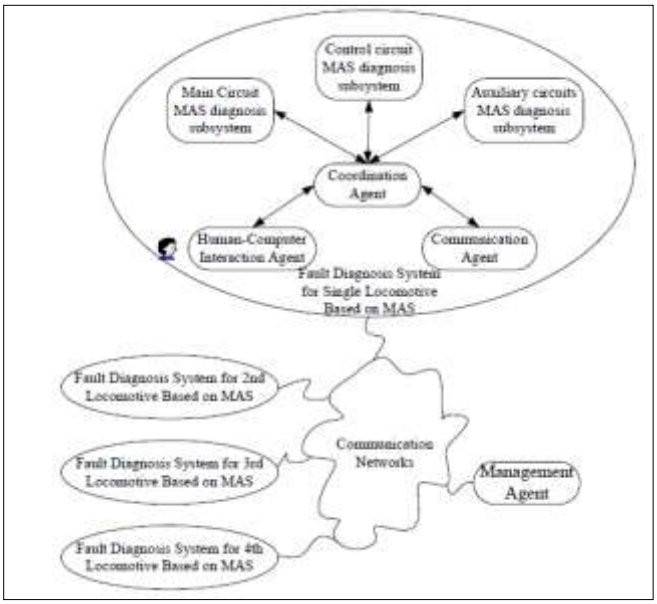
The electric locomotive fault diagnosis system based on MAS has the following advantages:

- speed-up and efficiency
- robustness and reliability
- scalability and flexibility and low costs

In the field of fault diagnosis, the advantages and characteristics of intelligent diagnosis equipment based on multi-Agent system may be inferred that many Agent systems can be applied to the field of fault diagnosis. The scholars that study MAS have analyzed the distributed equipment fault management in intelligence technology in detail and give a simple method of system design. At the research questions in real time monitoring, German researchers used Multi-agent mechanism to solve the problem of distributed monitoring and to give the monitoring model and functional package. National University of Singapore researchers put forward and set up a Multi-Agent Remote Fault Diagnosis System Architecture, and tested two cases in the Java environment. T. Nagata of Japan implemented Multi-Agent power supply system , Monitoring and emergency recovery project, and proposed the multi-agent communication mechanisms for consultations and information mechanisms . Wang built a nuclear power plant fault analysis and control model by using MAS technology, constructing MAS by the Heterogeneous Agents which are distributed on computers in different locations, completing the coordination of monitoring and diagnosis mission. Tsinghua University focused on multi-Agent based on the theory of mission decomposition and control strategy and Agent coordination and cooperation. They put forward serial and parallel hybrid control strategy . Southeast University Professor Zhong Binglin proposed multi-agent fault diagnosis method based on behaviour, and give the system's implementation strategy, and used "bottom-up" reasoning method to solve the problem.

MAS Fault Diagnosis System:

Fig 9. Fault Diagnosis System Structure of Electric Locomotive



The electric locomotive interior environment is quite bad, for instance working conditions temperature from -20 Celsius degrees to 70 Celsius degrees, and because it has perceptual devices inside such as big AC motor, so it has strong electromagnetic inside. These environment factors all increased the difficulty for primary signal gathering and processing. Because of the locomotive disturbance, the signal, especially the analog signal has a certain degree of randomness. In view of this kind of complex situation, a new data characteristic extraction method that has realized the signal characteristic extraction is proposed. It is the data cluster algorithm that based on immunity evolution agent. This algorithm has been the foundation for the whole fault diagnosis system.

Some electric locomotive faults have overlapping or the relatedness. This kind of faults possibly is caused by many components or many sub-systems. Generally speaking, each agent subsystem only is responsible for function relatively independent part of components or the subsystem. Therefore this kind of overlapping fault recognition and processing needs many agents to cooperate together.

Also some kinds of situation the many parts that producing this overlapping fault also have the possibility simultaneously to cause other kinds of faults. In this kind of situation requests that many agents simultaneously cooperate to process many goals. For the above situation, it is proposed by a MAS-based multi-objective co-evolutionary algorithm. With the help of this algorithm, the complex faults that originating in a number of components can be solved. Electric locomotive system is a flexible system. Single section, two, four or even eight reconnection can be found. MAS-based fault diagnosis system for electric locomotive of the overall framework is shown in Figure.3.8. Each locomotive is a relatively independent system, connected by the MVB communication network between the locomotive to the management Agent to form an organic whole. Single MAS is responsible for the single locomotive section fault diagnosis. Management Agent is responsible for coordination and manages all single-vehicle MAS, which makes the whole system can not only link locomotive on the single fault diagnosis, but also can unit the entire locomotive fault diagnosis. The various parts of single locomotive MAS are introduced as follows:

Main Circuit MAS diagnosis subsystem:

The main circuit is involved of the pantograph, the main circuit breaker, high voltage current transformers, main transformers, surge switch, rectifier devices, traction motors, high voltage electrical cabinets, flat-wave reactor, the transition reactor, excitation power screen, brake Resistor cabinet and circuit protection devices, etc. Its main function is to produce the locomotive traction and braking force. The MAS main circuit diagnosis subsystem diagnoses mainly directed against the above-mentioned electrical equipment. (Fig8). Each subsystem block diagram is shown in fig9.

Auxiliary circuits MAS diagnosis subsystem:

Auxiliary circuit primarily includes traction fan, air compressor, brake fans, pumps, split-phase capacitor start and the driver's cab of hot air heating device, heating furnace for oil compressors and pressure regulator switch room heating device and corresponding electromagnetic components such as contactors. It is the basic circuit to guarantee running of the main circuit power and to achieve the performance of the essential circuit. The MAS auxiliary circuit diagnosis subsystem is mainly designed to diagnose the above-mentioned electrical equipment (fig.8). Each subsystem block diagram is shown in fig. 9.

Control circuit MAS diagnosis subsystem:

The function of control circuit is that the driver gives command to control locomotive circuit and auxiliary circuit through the control circuit indirectly, which can complete the operation of a variety of working conditions. Control circuits are low-voltage circuit for the sake of security. 8G electric locomotive control circuits consists of the 110V DC power supply, batteries, as well as locomotive traction control, brake, forward, backward, accelerating and parking. The MAS control circuit diagnosis subsystem is mainly designed to diagnose the above-mentioned electrical equipment (fig.8). Each subsystem block diagram is:

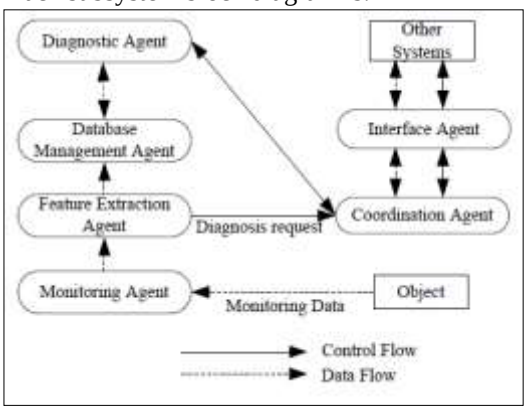


Fig. 10. Subsystem Structure

Communication Agent:

This agent is responsible for the external network to send information and receive network information from the outside, which controls the connection among locomotives and the connection between locomotives and management agents.

Human-Computer Interaction Agent:

The Agent is the MAS system's external interface. The agent provides interactive human-computer interaction interface and implements data extraction and analysis functions. HCI Agent users receive diagnostic results.

Coordination Agent:

The Agent's function is to coordinate each of these agents' relationship of MAS. This reduces the complexity of diagnostic systems, so that the logical relationship between Agents becomes more clearly.

Management Agent:

The agent's function is to manage the relationship of MAS fault diagnosis system among sections of locomotives. Management Agent solves the diagnosis coordination problem through the communication Agent of sections of locomotive system. Thus, it facilitates reconnection of locomotives and increases the flexibility of the system.

The Subsystem shown in Fig. 10 is the diagnosis of MAS framework of a single object. Each agent completes the object of fault diagnosis through the collaboration simultaneity. It can also diagnose the United-fault or cross fault with other MAS subsystem through the network. Specific work flow is as follows: monitoring agent collects the related data of diagnosed object. It extracts the fault symptom by using characteristic abstraction. When there are abnormal events, monitoring agent send the diagnosis request to coordination agent, which will run the related diagnosis agent to start fault reasoning. The result will be reported to coordination agent. The coordination agent can also get other system information from interface agent to aid fault diagnosis. The database management agent manages the database, such as the data classification overlapping and relatedness type. From the literature it is analyzed the advantage and disadvantage of existed electric locomotive fault diagnosis technology, and on this basis, proposes MAS-based fault diagnosis system framework for electricity locomotive electrical system. The paper explains the MAS system construction in detail and introduces the design and implementation if the software system and hardware system.

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